AN EMERGING PROCESS OF BUILDING MODELS
FOR MANAGEMENT DECISION MAKERS

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This is a working paper in the true sense. Comments and criticism are invited. It will become part of a monograph of wider scope to be entitled "Building Models for Decision Makers: An Application to Family Planning".

ABSTRACT

This paper draws on the literature in management science, behavioral science, and information systems along with practical experience to propose a process of building models that will be implemented. The steps are: (1) formulation of priors, (2) entry, (3) problem finding, (4) specification of model development criteria, (5) model building, (6) estimation and fitting, (7) tracking, and (8) continuing use. After describing the state of the art of model implementation, each factor is discussed. The paper closes with a preliminary identification of research needs in this area.

ACKNOWLEGMENTS

The author owes credit to many people. The content of this paper reflects discussions with many practitioners and academicians and the paper probably contains, without explicit citation, many of their thoughts and experiences. John Little's direct and indirect influence on my thinking was most significant and is gratefully acknowledged.

An Emerging Process of Building Models

for Management Decision Makers

by Glen L. Urban

Introduction

The volume of publication in Management Science and Operations Research, numerous books, a multitude of seminars, and a substantial community of MS/OR professionals document the amount of effort put into managerial model building. But the reported amount of implementation of models, managerial impact, and decision payoff is very small. For example, Management Science: Application contained 70 articles in 1971, but only 3 represented implementation in an organization and only 10 more were applied even once in a real decision situation. In Operations Research the percentages are even lower. The degree of data basing is a weaker criteria of inclination toward application, but even in this dimension only 40 percent of the articles in Management Science: Application supplied any empirical support at all.

It is difficult to document the exact level of implementation by publication because there is a tendency for field practitioners not to report really successful applications,since they may be viewed as proprietory, or failures,since this may imply incompetence. As a result, the literature tends to include rather mediocre applications when it contains applications at all. Private model builders also place low priority on publication and along with the delays and the difficult work associated with publication, the number of reported applications in professional journals is minimized. The percentage of articles in Management Science: Application even partially authored by non-academicians has been decreasing and was below 15 percent in 1971. This trend is being reversed with the advent of the Institute of

Management Science's Interfaces which allows a more convenient medium for practictioners.

With a lack of full knowledge of implementation, it is difficult to explicitly define the state of the art, but based on the author's discussion with practitioners in companies, the literature, and management seminar discussions over the last five years, figure one seems to be a reasonable description. Implementation is divided into: 1) experimental use - first trial, (2) emerging use - wider testing, (3) continuing use by one manager, and (4) institutionalization - use by many managers on a continuing basis as part of their decision procedure. Decisions from control to strategic planning are represented on the second dimension. The graph should be interpreted analogously to a regression line based on individual applications representing points. Very simple models often used to present data to managers are not included in figure one. For example, a pro-forma balance sheet reflects the accounting model of the firm and sales reports may reflect a geographic model of the market. Many firms use simple format models to display data to decision makers. Some decision makers rely on such data and use it in their decision making. This would imply a high degree of implementation. It should be noted, however, that one is amazed at how very little of the data spued out by "information systems" is used. Figure one does not consider the simple structures used to retrieve and display data since consideration in this paper will center around formal mathematical models.

Control decisions such as determining inventory levels or distribution and production control seem to be the most widely supported by models. Although such applications are not nearly as sophisticated as they could be, a

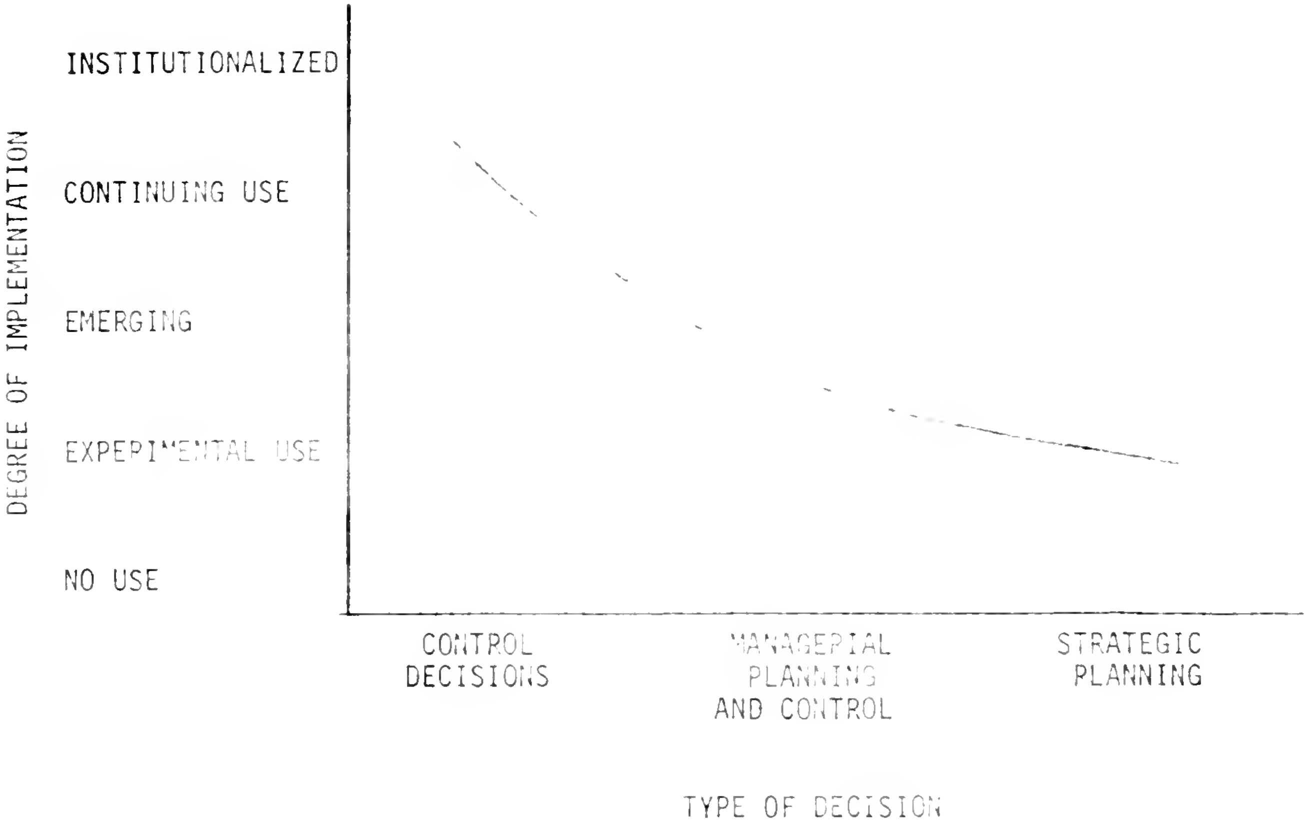


FIGURE ONE:

State of Art of MS/OR Implementation

number of firms are using such control models on a continuing basis. In considering decisions such as production scheduling, media selection, and forecasting, evidence can be found in some firms of model usuage. This is particularly true in the oil industry where L. P. models for production planning are used.[1] But, in general, fewer organizations use MS/OR models in planning than control and most are only experimenting. Models for the most difficult decisions of strategic planning such as new product development, mergers and acquisitions, and advertising budgeting have achieved little use. Although some firms have been experimenting, few firms use sophisticated models for strategic planning on a continuing basis. One exception appears to be Xerox, which is said to have an integrated strategic planning system institutionalized, but no published reports seem to exist.

Figure One indicates, as decisions from control to planning are considered, the degree model implementation drops. This correlates well with the need for more sophisticated models and the increasing absence of problem structure in planning. The state of the art also varies by functional area. The rank order of implementation is production, finance, and marketing. This rank order seems to correlate to the percent of structured versus unstructured problems in each area. In the public sector, the degree of implementation is even lower than in the private sector.[2] Although McNamara gained fame with PPBS, it does not appear to be an institutionalized procedure today. In softer areas such as health, education, welfare, and transportation where organizational diffuseness, lack of specific and measurable goals, poor data, and high political content characterize problems, few if any, models can be cited as being used on a continuing basis by a decision maker.

In general it seems that little of the vast effort put into MS/OR model building has yet paid off in terms of implementation and the improvement of organization effectiveness. This problem has not gone unnoticed, but it has not received the attention it deserves. Less than 5 percent of the papers in Management Science and Operation Research involve implementation research.[3] Only one of 70 papers in Management Science: Applications in 1971 was directed at implementation problems. The work in the literature tends to examine special aspects such as the need for mutual understanding and communication[4] the effects of cognitive decision styles[5], characteristics of successful projects[6], the factors underlying implementation problems[7], or the criteria for an implementable model[8]. Other works reflect narratives and "gems of wisdom".[9] There has been no integrated effort to define how to build MS/OR models that will be implemented. The largest body of relevant research outside of MS/OR is in organizational development. Several procedures for planned change have been proposed. The Klob and Frohman approach is the most relevant to the problem posed by this paper.[10]

The purpose of this paper is to draw on the author's personal experience, informal discussions with other model builders (practitioners and academic colleagues), and the published literature to advocate a process of how to build models that will be used by decision makers to improve their organizations' performance. This methodology is relevant to models for decision makers and does not apply as well to advocate models used to support argumentative presentations to decision makers. Such models may be an effective method of influencing decisions, but the implicit postulate of this paper is that models will be most effective in producing organizational payoff when they are used as a tool by the manager himself in his decision making.

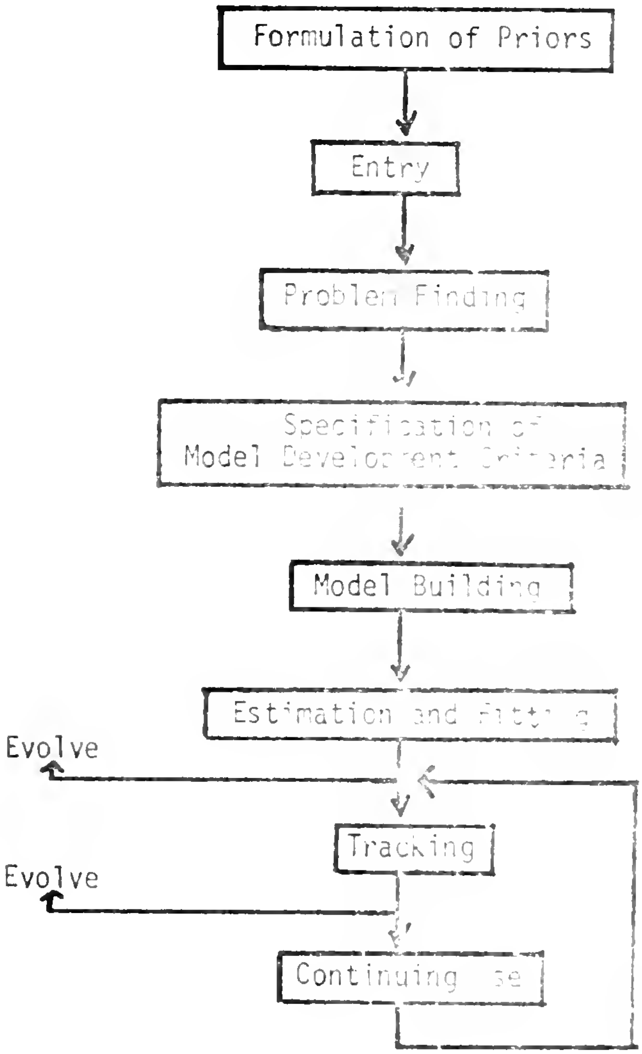
Overall Process

The overall process for building implementable models is described in figure two. It begins with the consideration of priors, proceeds through entry, problem finding, specification of model development criteria, model building, estimating, and tracking to end in continuing use. This structure is not meant to be rigid. In most situations iteration will take place with more feedback than the major evolutionary feedbacks indicate. But the model builder should be careful to consider each step and the issues associated with it. It is most important for the model builder who is serious about implementation to consider application throughout the process. Building a model and then implementing it is not a good approach. The model itself will be substantially different if implementation is considered throughout the effort.

Priors are important to recognize since few model builders realize the biases their past training and attitudes bring to a problem. Model builders should have a "tool kit" of OR and statistical approaches rather than one pet technique. As a tool kit is used, updating will occur and posterior estimates of appropriateness will be formed. Good prior thought about the specific problem area is necessary for the model builder to legitimize himself to managers and it sometimes requires "selling" to gain entry. Care should be taken in determining the entry point so that decision leverage can be gained. At entry, education efforts should be carried out since this will facilitate communication and lead to effective problem finding. Most model builders attack the wrong problems (at least from the manager's point of view) so substantial effort should be allocated to identify the correct first project. This calls for empathy on the

FIGURE TWO:

Emerging Process of Building Models for Decision Makers



model builder's part and a diffuseness of his priors that will allow him to accept problem definitions different from his prior thought.

Given an appropriate problem, specific model building criteria pertaining to implementation, model specification (factors, phenomena, and variables), and data should be formulated. These become, along with resource constraints, the basis of selecting the level of detail for the model and the model type most appropriate. It is important to consider alternate model forms at this point and make explicit modeling and managerial tradeoffs. With a first model structure, data is examined by linear and non-linear statistics. Empirical data is combined with judgment to fit past data. Lack of fit may require feedback to re-define the model criteria or structure. Since managers sometimes do not know what they want until they see it, the re-cycling may go on as far back as problem revision.

After an appropriate managerial model has been shown to fit past data well, it can be further tested by use in the decision process. Such use will generate forecasts which over time can be compared to actual results. This process is called "tracking" and includes a diagnosis to find if the parameters or model structure need to be updated. The diagnosis may also identify new problems that will require other models or elaboration of the existing model.

The final step in the modeling process is continuing use. This is a process of widening use within the organization and institutionalizing it as decision procedure. Continued tracking will probably lead to new model evolution, other models, and an increased confidence in the validity of the model structure.

Each of the elements will now be discussed in detail and this paper will end with a brief indication of tests of this methodology and future research needs.

Formation of Priors

Few model builders realize the strength of their priors even though they can clearly see others who are biased towards one particular approach. These favored approaches may be specific techniques like math programming and econometrics or functional orientations of marketing, production, or finance. Some researchers seem to find all problems fit into a particular model structure like a Monte Carlo or industrial dynamics simulation. Figure 3 represents the conviction that: (1) problems should lead to models, (2) solutions are gained by applying techniques (e.g., simulation, math programming, heuristics) to the models, and (3) data interpreted through statistical models are used to estimate models. In this view the researcher should have a tool kit of OR/MS and statistical techniques, as well as, a number of alternate model building approaches so that he can effectively solve problems. This is in contrast to the approach of taking a technique like math programming and forcing the problem to fit it or taking a statistical approach like regression and abstracting the problem aspects that can be analyzed by this procedure. It is best to be capable of applying all significant techniques and to utilize the appropriate one in a given problem setting.

It is not undesirable to have priors on technique and approach, but care should be taken to initially build rather diffuse priors and a wide range of skills. Initial training for model builders should

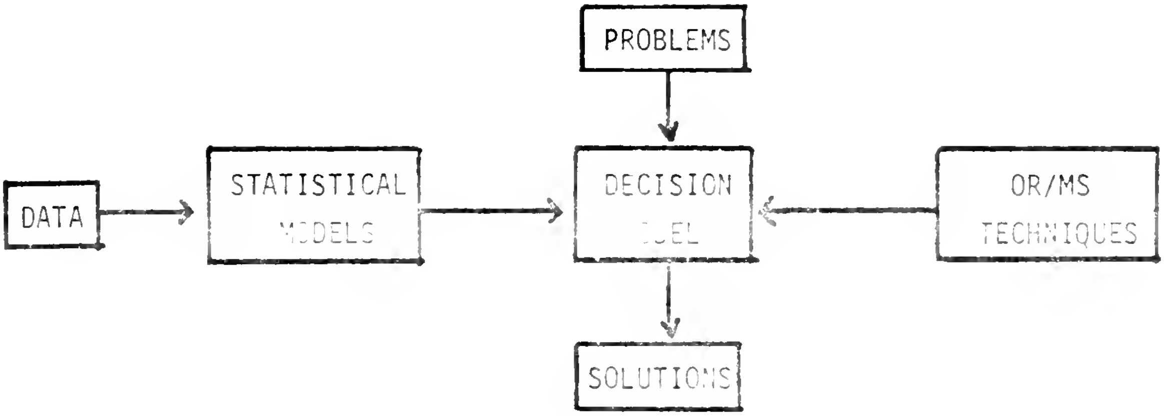


FIGURE THREE:

Decision Modeling Approach

include the basic disciplines of economics, behavioral science (especially organizational and consumer behavior), quantitative methods (OR and statistics), and functional management approaches. This should be followed by actual model building experiences in real environments, as well as, the study of a range of existing models. This should provide the student with a set of capabilities which can then be modified by experience. Evidence indicates that in general people are too conservative in their updating of priors.[11] Model builders should be sensitive to experience and, through applications in many problem situations, build an effective tool kit of alternate modeling, statistics, and solution capabilities. If priors were correctly formed by initial training, experience should lead the model builder to update his priors so that he has a portfolio of approaches that could work well and a feeling for the kind of problem areas where he can have impact.

It is usually necessary to have fairly concrete priors if the model builder wants to enter a real environment, since he will have to sell himself and establish his credibility. These specific priors can be generated by studying the decision environment, talking to people in the field, and from the literature. The model builder should consider a range of general models that could contribute to the real problem area. With this thinking and his past achievements, he should be able to make an effective entry.

Entry

The process of entry into the organization is very important. It is recommended that entry be made at the decision point. This is where the leverage is and if the model is to be used by the manager, it is best to work with the decision level as soon as possible. A good first contact and an essential activity is an educational program about models, management science, and information systems. This should be top management oriented and could be done in a one day seminar at the office or in conference at a "pleasant" location away. This education should include discussion of terms and other applications, but emphasize specific "hands on" model experience. In some companies the educational task already has been carried out, so informal tutorial sessions with each manager may be most appropriate. In others where there is no experience, some very brief project to build a simple model may be needed to provide relevance for the educational effort and to demonstrate the capability to understand the individual organization's problems.

If the educational effort is unsuccessful and management is willing to look into the potential of models, a team should be formed with the relevant decision maker as its leader. The team should be small, but include in addition to a manager, one or two staff people, and a change agent. The change agent is particularly important.[12] He is a man who can effectively work in the informal organization to advocate and gain acceptance of the innovation of models. His capabilities must be greater in organizational development than in model building. This team must be backed by top management support. The president must approve of the work and decision makers must perceive that the effort they put into the project

will be valued.

In addition to top management support, a commitment of time and funds must be made. The time commitment by managers inside and outside the team to aid in model building is the most important, although initial funding is not trivial in many cases. Particularly in public sector work, "seed money" is an effective way to fund feasibility and initial work. But even in these cases it is advisable to have the organization budget some funds, however small, since this builds commitment, interest, and evaluation into the project. The model builder must be careful not to orient his work towards the funder, but rather towards the manager who will ultimately make the project pay off by improved decision making.

Problem Finding

Given the commitment and resources to pursue model building, effort should be concentrated on finding the most appropriate problem. Priors may have been used to identify potential problems and to form the team membership, but now a substantial effort should be made to find the best problem to work on first. Experience indicates 14 to 21 man days is sometimes necessary to effectively define the correct problem. Many modelers skip over this problem finding step and assume they have a good problem definition only to find at completion of the project that it was not the problem at all or at least not the one that interested the manager.

A good way to find problems and understand the organization's needs is to carry out a descriptive study to determine: (1) existing models or rules of thumb,[13] (2) the characteristics of the decision process (who makes decisions, when, and on what basis?), (3) the existing flow and usuage of information, (4) the clientele's behavior and relationship to the organization, (5) the stated and apparent goals of the organization, (6) the informal and formal organization structure (including power, friendship, and authority

relationships) and (7) managers' definitions of their perceived problems. This could be done by extensive interviews with managers, a study of recent and on-going decisions, probing questionnaires, and consideration of managers' self designated perceptions. This process calls for a great deal of empathy on the model builder's part and a willingness to revise his prior designation of problems. He must be sensitive to their needs and stated problems, but he must realize that managers may not know what their problems really are. For example, a manager who is experiencing a profit decay may feel it is a cost problem when, in fact, the marketing strategy is the basis of the problem. If the model builder perceives a different problem it would be wise to start with the manager's problem, but have an explicit evolutionary plan that will lead to the manager's gaining a perception of the wider problem. Rockart has found that comparison of a normative model generated by the analyst when compared to existing procedures can help find problems.[14] In a clinic scheduling problem, he found a comparision of a normative job scheduling model to existing procedures identified over two-thirds of the problems eventually found by an extensive problem definition exercise.

The problem finding study will yield many topics and the selection of the first project must be made. In general, it should be a "simple" problem that can be done within the existing state of the art of MS/OR and one that can be easily understood by managers. It should be a significant and visible problem. Since managers will have to devote time to this project it must justify such effort. Visibility is important in gaining recognition and a base for future work. A good rule is to work in an area where a large budget is involved so that gains from the model building will be large. The first project should be low cost and produce some results in a reasonable time (less

than six months). It should involve managers and be interesting to them. Finally, it is desirable to work in an area where relevant data exists. Clearly, it is only in a few cases where all these criteria can be met. The highest priority is on managerial interest and involvement, assuming the model builder can do the job.

After selecting the project, a specific psychological contact should be made between the managers and team members that includes an understanding of goals of the project, individual goals, resource commitments, the relationship between members and the organization, and the specific scope of the work.[15] It is useful at this point to visualize the likely outcome and carry out a rough cost benefit analysis. An exercise of this is to try to write out the memo that would be sent to top management after one year of the project to document real gains and payoff. At this point the team composition may also be revised. Since it is important to have the real decision maker on the team, the manager involved in the project's decision may be added as the new team captain or as a member. In some cases, a whole new team mav be formed since the first team had performed its functions of organizational legitimization and problem finding.

Model Development Criteria

Given a good problem and a clear understanding of the project activities, specific model development criteria should be formulated. First, is the model to be descriptive, predictive, or normative? A model that forecasts well may be very different in structure from a normative model. An exponential smoothing model may be a good forecasting model, but be useless in determining what level of advertising and salesman compensation should be set.

Next the factors, phenomena, and variables important in the problem should be listed and rank ordered in terms of priority for inclusion in the model. Particularly, the phenomena of consumer or clientele behavior to be included should be explicitly considered. The physical, organizational, and external constraints should be listed and the opportunity for data basing examined. Model development criteria should be set in terms of inclusion of variables, factors, and phenomena along with policies stated in terms of constraints and a view towards the degree of empirical content. In the case of normative models, the criterion to be used to define "best" or "optimal" should be defined, if possible. In some cases meaningful goals cannot be specified until the model is structured and managers have interacted with it and increased their level of perception. Finally, the criteria should include specification of the evolutionary steps that will lead to the described final model. These criteria will be important in the tradeoff between alternative models.

In addition to criteria relating to model purpose and scope, explicit implementation criteria should be set for the model. Little has proposed a set of criteria for models that will be used by managers. He suggests a model be: (1) understandable, (2) complete, (3) evolutionary, (4) easy to control, (5) easy to communicate with, (6) robust, and (7) adaptive.[16] These criteria will be reviewed here with a few changes from Little's work.

The first criterion - understandable - requires a simple model structure that is perceptibly similar to how the manager thinks. For example, process flow models are usually intuitively acceptable to managers, while generally a linear programming equation is not. If the model is not a process model, it will

be more understandable if it can be represented graphically and with a minimum of mathematics. Understanding applies not only to the manager formulating a plan, but to the levels in the organizational hierarchy which review plans. If the model is not understandable to middle and top management they probably will not accept the new decision procedure, and the model will not be an effective communication mechanism.

The second criterion is completeness and it demands that none of the factors or phenomena important to the manager's definition of the problem are omitted. This is in conflict with the first criterion since most decisions are complex and completeness implies a model that is difficult to understand. Criterion three allows an escape from this conflict. If a simple model can evolve to a more complex model in an orderly manner, the manager can be taught the basic structure at a simple level and then evolve to a complete and more analytical model.[17] The evolutionary criterion also implies building a model that can be generalized to many situations from the initial application environment.

Perhaps the most important criterion is control. The manager must feel it is "his" model and that it reflects a refined statement of his implicit model. The model, if it is to be used on a continuing basis, must be viewed as a necessary tool for his work. He must not feel that in using the model he is delegating his decision prerogatives, but rather that the model is helping him to exercise them. The manager should control the model to the extent that he could manipulate the model, if he so desires. That is, he should know the inputs necessary to get specific outputs.

A complete and understandable model encourages the feeling of control, but the use of on-line computers has made it feasible for the manager to directly interact with a model. The use of a good conversational program

and graphical display allow a manager to communicate easily with the model from his office via a remote terminal. This element of control and ease of use are important to the internalization process.

The process of acceptance can be reinforced by a robust model. The model should not produce wildly unexpected results. For example, a linear advertising budgeting model is not robust since it will lead to an optimal level of advertising at plus infinity or zero. The model should be structured to give reasonable answers and the output be restricted to reasonable ranges such as the limits of the data used for estimation. In using a robust model, the manager gains confidence and is not distracted by inappropriate asymptotic outcomes.

Given a model that meets the above criteria, the next question is how the model parameters will be obtained. A model will be more heavily used if its parameters are data based. Initially, in order to meet the completeness criterion, it will obviously be necessary to rely heavily on subjective inputs, but the use of the model will aid the manager in specifying his data needs and encourage him to use the data after it has been collected. In some cases, historical regression is informative about parameters, but in most models where causual inferences are required, they can be gained best by experimentation. The most ideal data basing system is one that utilizes continuing experimentation and permits adaptive control. In this way, the model can be updated to reflect changes in response while the continual updating and refining will build managerial confidence in the new decision structure.

During the parameterization and updating of the model, it is important to allow managerial judgment to enter the process. The model should be

structured so that the manager can relate his experience to the parameters. It may seem unnecessary to require this if experiments are conducted, but experiments tend to be confounded by uncontrollable factors (e.g., competitors and local market changes) and the causative effects are sometimes small relative to the variance in sales.[18] This means the statistical results may require interpretation before use in a normative model. This interpretation is facilitated if the manager understands the model.

After specifying the decision calculus criteria for an implementable model, a set of criteria on completeness and inclusion of factors, phenomena, and variables, a definition of the constraints, and a policy on data basing, model construction can begin.

Model Building

Model building tends to possess the characteristics of an art. The model builder has available many alternate forms and he tries to interpret and structure a somewhat nebulous problem with them. In the same situation some people can create beautiful models which represent perceptive structuring of previously unstructured problems, while others shape awkward and unconvincing models.

Some emerging ideas to help at least position alternative model forms will now be discussed. With this classification of model types and the previously specified model development criteria, the most powerful structures should be evident. Within this restricted set, structuring and alternative model tradeoffs should be easier.

Table one shows decision models divided into aggregate response, hierarchical, and perceptive groups. The aggregate response models are models based upon an independent variable being a function of a set of dependent variables. These tend to be multiple and sometimes simultaneous

equation sets. They model the response of each dependent variable on the independent variable and changes in one variable can compensate for changes in another. Math programming and econometrics are most commonly used to analyze these models. The second major class of models are hierarchical. They are either sequential decision or flow type models. Events do not occur at one time as in aggregate response models, but rather occur in an ordered sequence. Examples are Monte Carlo simulation, industrial dynamics, or other macro flow models which are structured as dynamic and deterministic flows. These first two classes are further divided into stochastic and deterministic sections. The third type of model is called "perceptive" because their major purpose is to reveal new insights for management. Examples are market structure models based on non-metric multidimensional scaling, information processing models, or organizational models. It should be noted that aggregate response and hierarchical models also help managers gain new insights by explicitly modeling the decision environment. The footnotes to Table one cite some specific examples of each type of model. The table does not name all existing types of models, but it is hoped that it contains the major model alternatives.

Considering the development criteria, the choice of perceptive models is possible only if the criterion was to build a descriptive model, so the most difficult choice is between aggregate response and hierarchical models. The basic nature of a problem may clearly indicate one approach. For example, since people flow through a medical system, a sequential model is attractive. But aggregate models have also been used to analyze health systems.[33] While the problem itself will help in the

TABLE ONE:

A Classification of Decision Model Structures

Aggregate Response

Deterministic [19]

Linear - non-linear, univariate - multi-variate, static - dynamic, and/or single - simultaneous equations

Stochastic

Risk analysis [20]

Econometric [21]

Expected response [22]

Hierarchical

Deterministic

Macro flow models [23]

Industrial (systems) dynamics [24]

Sequential analysis [25]

Stochastic

Monte Carlo models [26]

Markovian Models [27]

Queueing [28]

Bayesian decision analysis [29]

Perceptive

Market structure models [30]

Attitude scaling [31]

Information processing [32]

choice, the basic level of detail needed is an important determinant. In general, the flow type models are more detailed than aggregate response models, but within each class different levels of detail are possible. Consider the level of detail tradeoffs shown in figure 4. As the level of detail increases, the model is more difficult to estimate, solve, and test, but a richness expressed as behavioral content in consumer models or feedback dynamics in system models is gained. The specification of the model development criteria relating to the phenomena and factors to be included in the model helps in the choice. If a high degree of heterogeneity and feedback response must be encompassed, a flow model will be appropriate. If more macro and compensatory phenomena are to be modeled, then the aggregate response model is appropriate.

The most important factors in the choice of the model are reflected in the decision calculus criteria. Does the manager basically see it as a flow or a response? Which type is most compatible with his existing or implicit model? It is strongly recommended that the model be very compatible to the manager's view of the decision environment. The model should evolve from a simple version roughly similar to his implicit model to a more complete and powerful version. This initial version must feel comfortable to the manager if he is to understand it and he must feel that he controls it. It must be remembered that the new model will be in competition with his old model.

The choice between deterministic and stochastic models may be dictated by the development criteria of the problem, but in general, managers have enough trouble understanding deterministic concepts. It is suggested that, in most cases, stochastic aspects be added well down the path of evolutionary development.

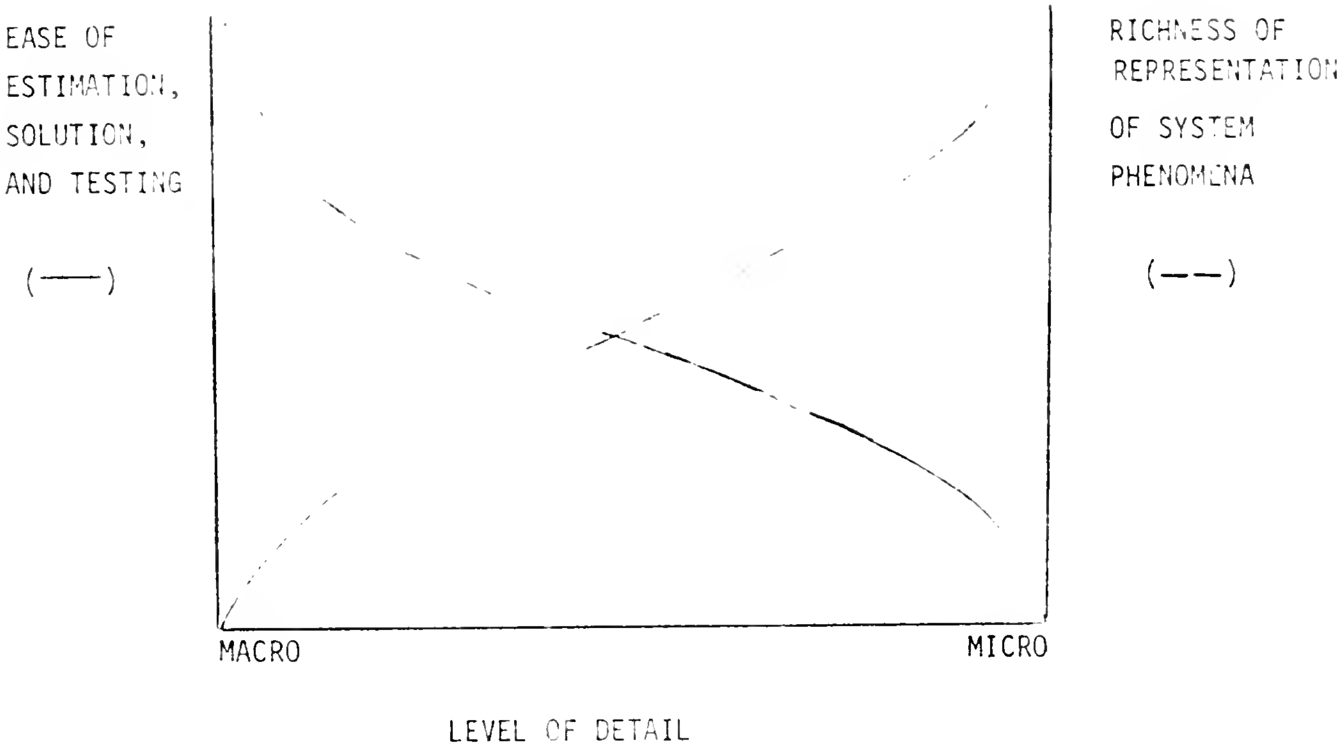


FIGURE FOUR

<u>Some Level of Detail Tradeoffs</u>

Final considerations in the choice of level of detail are the budget, time, and personnel available. In general, more detailed models cost more, require more managerial time, need more real time to complete, and are more subject to problems of personnel turnover. To the extent that flow models initially or during evolution are more detailed, the aggregate response models would be indicated if budget and time constraints are severe.

It is clear from the previous paragraphs that a great deal of art remains in model building. It is hoped that the classification of model types and level of detail dimension interpreted through the model development criteria will help restrict the search to a few relevant alternatives. Within this set, models should be roughed out for each alternative type and evaluated by the model builder and manager to make a decision on the best approach. Given the best model structure, the researcher must refine the interpretation of the problem in the model and satisfy the model development criteria. This process can be facilitated by continued interaction between the model builder, manager, and the development team. During this process, the model usually grows too large and complex and continuing pressure must be applied to keep the model understandable for managers. This can be done by setting priorities on complexity and developing an explicit evolutionary development plan. As the first simple but meaningful model is developed, it can be combined with data and judgments to lead to initial use.

Estimation and Fitting

Data for model building can come from subjective judgment, the analysis of past data, or experimentation. The statistical analysis of

past data is best understood. Linear regression procedures can find the best fitting parameters given the assumptions of the statistical model. Many times, however, the simple linear model is not an appropriate representation of the decision model so that transformations, lagged terms, or simultaneous equations must be used. This raises a number of statistical issues of bias and consistency, so model builders must be careful not to inappropriately apply regression. Carrying out a synthetic data analysis can help determine the bias that might result from applying simple procedures to complex models. For example, artificially generating data from a hypothesized nonlinear lagged model and repeated regressions on generated data can be used to estimate the bias in the estimates for a given sample size.[34] If the bias is acceptable in this synthetic-setting, ordinary least squares regression could be used. In simultaneous equations the situation is more complex since procedures demand that "identification" conditions be met. But in many managerial models (e.g., industrial dynamics) the number of exogenous variables is small and systems are under-identified. Some modelers add exogenous variables to provide indentifiability, but this is a dangerous method of achieving the statistical compatability.[35] It is not good practice to add variables that were not hypothesized in the decision model unless a new justification for inclusion is found. The statistical procedures should not over rule the decision model and its managerial relevance.

In regression analysis various transforms are available and in some situations can be used to create decreasing returns, hyperbolic, or even "S" shaped responses. These transformed models are called intrinsically linear. Not all models can be transformed,so non-linear estimation procedures may be necessary to minimize the squared error or maximize a likelihood function. These techniques are indirect procedures based on solving the set of partial

differential equations or direct computer search routines.[36] Although these procedures impose few conditions on the model, with the exception of maximum likelihood, they supply no statistical output and the analyst must interpret the significance of the explained variation and the coefficients.

Most historical data in managerial settings is not very clean. Typically the variations in variables is small and data tends to be heterogeneous. For example, in marketing the data base may be time series of sales data and cross sectional attitude surveys. The best method of collecting data is by experimentation, but this is expensive, and sometimes it does not yield the significant results desired. In most situations the data analysis reveals gaps, inconsistencies, and a fairly wide variance on parameter estimates, so subjective estimates must be used. It is better to use subjective judgment than to sacrifice the completeness of the model necessary for managerial implementation. If an important parameter is not known, the manager will request relevant data since he can see through the model how it would help him.

Subjective estimates may be combined with the empirical estimates by "fitting" the model's dependent variables to a past set of values. This is facilitated by an on-line model since the manager then can make his estimates and see their effect in terms of improving the fit. This type of procedure is manipulative and enough degrees of freedom usually exist to perfectly fit the data. It is important for the manager to consider only reasonable parameter changes and justifications should be sought for various estimates. The model builder must remember that the judgments made in fitting will be tested by prediction in the tracking stage. It is good practice to save some past data for predictive testing, if enough data exists. Then a

test of the quality of fitting will exist before usage.

Based on the fitting exercise, the model may require revision due to a lack of fit or the discovery of new phenomena or factors. Managerial interaction at this level may also generate new model needs or even problem elaborations. These adaptive requirements demand that the model be implemented in a very flexible computer program so it can be readily revised by adding new parameters and functions with a minimum of time and cost.

Given the evidence that the model adequately fits past data, it can be used. This initial usage is usually on a small scale, but should involve real decision level interaction. This use will lead to decisions and forecasts and provide a basis for tracking and expanded usage.

Tracking

In tracking, the forecasts of future events are compared to actual results and the differences must be reconciled. They may be due to: (1) errors in forecasting model inputs, (2) inappropriate parameter estimates, (3) incorrect model structuring (4) changes in the real environment being modeled, or (5) random variation. Separating these causes for differences between predicted and actual requires a great deal of judgment. First, one can see if input forecasts are in error by comparing predicted and actual input levels. Re-running the model with the actual input will remove this first source of error. Parameters should be re-estimated for the new period and formal Bayesian or informal procedures used to update the parameters. Re-running with the updated parameters and subjective fitting will assess the adequacy of current model structure. In many situations it is found that either the initial structure was not complete (e.g., no competitive

price variable) or the world changed (e.g., price controls). The reconciliation is a re-fitting of the model to the new data and is an updating of assumptions that will allow a new conditional prediction. This adaptive use of the model should be continuous and will lead to confidence by managers in the model and establish the model's "validity".

The discipline of reconciling predicted and actual results often identifies new problems. For example, the difference between actual and predicted sales may be due to out of stock condition in one distribution sub-channel or a change in competitive strategy. The manager's interaction in the tracking gives him an effective problem finding and control mechanism and often leads to the specification of new models or data collection needs.

Continuing Use

As a model is used over time, tracking increases managerial confidence in the model and usually leads to elaboration and evolution. The evolutionary progress is almost continuous with not only model changes, but new model needs being identified. This leads to a model bank which is a set of compatable models designed to meet special decision and managerial needs. The data necessary to support these models should evolve as the models are developed. The growth of the data bank, model bank, and statistical capabilities should be balanced.[37] The view of this author and others is towards model based information systems.[38] Figure five describes an example of a model based time pattern of growth leading to a total decision information system. This is in contrast to efforts to build initially a "total" system which generally have not been successful. It is also contrary to the notion of building the data base first and represents the view stated by John Little that"the model is the stone in the shoe of data."

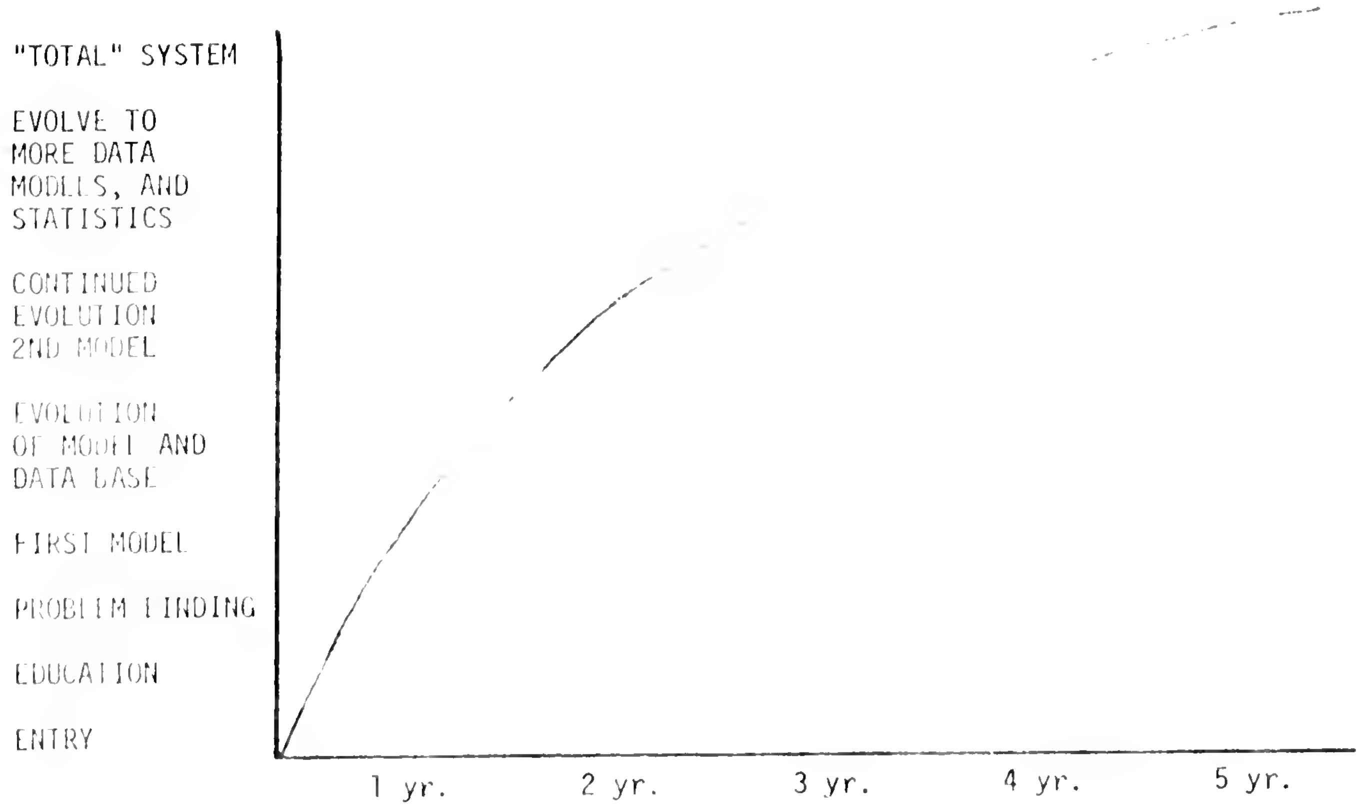


FIGURE FIVE:

An Example of an Evolutionary Development of a Decision Information System

During continuing use, efforts are made to diffuse the innovation of models to other managers. It is particularily important to gain acceptance at the middle level where the experience of many past years has left a sometimes inflexible implicit model in managers' minds. It is easier to gain acceptance at the operating manager level since these people are generally younger and more innovative. It is also easier at the top level where organization innovation is at least stated as a virtue. During the diffusion of the model through the organization, a hierarcy of models may be required since perspectives and data bases change at different levels in the organization. The information system's model bank will contain models differentiated by decision and level.

Experience with managerial implementation has often indicated that acceptance is most easily obtained from the decision makers who "suffered" through the development. This implies that diffusion horizontally and vertically in the organization will be most successful when new managers are involved and feel that they are building their own model. It may be best to efficiently "re-invent the wheel" with a model building system structured around the initial model.[39] Not only will this promote commitment, understanding, and a feeling of control in the managers, but it also provides benefits for the manager. Some managers feel that the exercise of model specification and building are as valuable as computerized usage. Figure 6 shows a hypothesized plot of perceived managerial value versus the model building evolution. High initial value accrues to the manager as he structures and internalizes a previously unstructured problem. He is updating his mental model and usually gains from the new more complete and analytical formulation. Additional benefits of better understanding, forecasting, and decision making occur in computerized model estimation

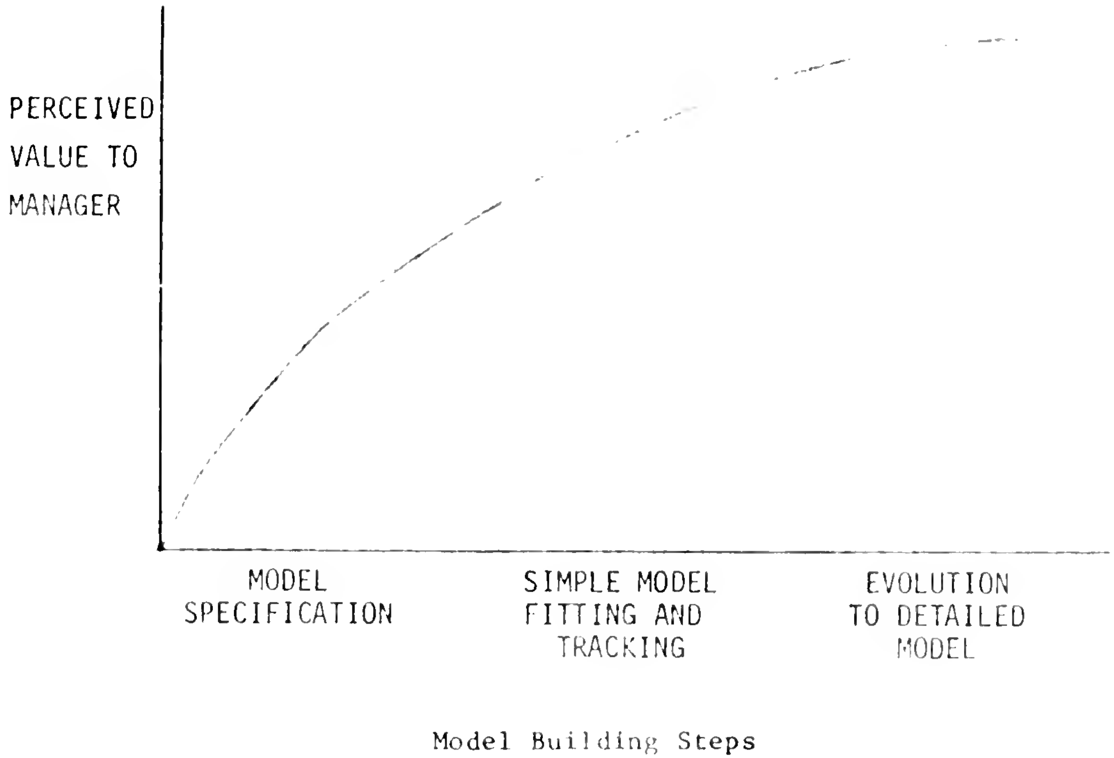


FIGURE SIX

<u>Hypothesized Managers Perceived Gains vs. Model Building Steps</u>

and use. Diminishing returns to increased model detail then set in due to increasing costs and decreasing marginal utility to the manager. Eventually, the marginal returns could become negative as excessive detail causes loss of managerial understanding and control and as costs of estimating and running the model increase rapidly.

Another factor in determining marginal benefits is the time required from managers. If this can be minimized, marginal returns and acceptance will be higher. During the process of re-inventing and customizing, the commitment of managerial time can be reduced if customizing is largely selecting options from an extensive set of compatible modules. Then the model builder can build on-line "his" model. Time efficiency during continuing model use can be obtained by expressing the model concisely in a non-computer form. For example, a planning log documenting model runs and tracking efforts is useful since the manager can use technical assistants to execute his desired runs and summarize them in a concise form. Although on-line models are critical to managerial feelings of control and understanding, most managers tire of physically running the model on a continuing basis. However, they want the capability of quickly making runs on special occasions.

Maintaining creativity during continuing use is an important concept. Models do not create, they only execute what has been structured. The model and computer should do what they are best at and man should do what he is best at. If the model reduces the burden of routine work the manager will have more time to create. The model will help him explore the implications of such innovation, but the man must respond. This creative push can come by goals which demand creative innovation to achieve, by a committee which tries to create new decision alternatives not now in the model, or by an

explicit document requiring an identification of creative alternatives.[40]

During continuing use of most systems, a long run sustaining effort is required to respond to changing needs, train new personnel, and maintain commitment. Problem environments change and usually managers and or staff have high turnover rates. This turnover implies that customizing and training will be a continuing task. The model building, OR, and information systems personnel turnover is sometimes higher than managerial turnover. This combined with a general shortage of people capable of supporting model implementation implies that explicit programs are required to recruit and train the model building and implementing groups.

The comments in this section argue that it would be difficult to view implementation as complete, but rather that continuing inputs will be required to assure that the models meet managers' needs and are used by them. If a model is productive, over time the procedures will become institutionalized. For example, requiring model support for plans and instituting a protocol of quarterly tracking reports will facilitate implementation. The dynamics of the decision environment and organization will dictate an adaptive approach to implementation rather than a final institutionalization.

It is clear that if the process proposed in this paper is followed, continuing use of models will change decision procedures and organizational relationships. Explicit efforts should be made to monitor these effects and take action to assure effective planned change in the organization and effective implementation of models to produce better decision making.

Concluding Comments

This paper has advocated a process of building models that are to be used by managers to improve their decision making. It is inductively based on experience and deductively on the published literature. The

experience was gained by failures and successes in building and implementing new product models.[41] The process became explicit during a three year implementation of an advertising model.[42] The process was followed step by step in a family planning strategy model which is achieving successful implementation.[43] This by no means establishes the validity of the process, but it does provide confirmatory evidence. Little,[44] Adleman,[45] Scott Morton,[46] and Gorry[47] have also found success with approaches utilizing similar process concepts. Research is needed to experimentally find the best process. This paper proposes one experimental treatment. Other alternative procedures must be stated and suitable comparative tests devised.

Within the proposed process many research questions are unanswered. First, modeling remains an art and research into the process of structuring complex situations and selecting from diverse model alternatives is needed. The estimation of parameters requires non-linear procedures in many situations and statistics are needed for these cases. Work is needed to allow better judgmental inputs and improved procedures to combine empirical and subjective inputs in the complex models used in management decision making. Research on tracking is needed to separate the causes of deviation between actual and predicted results. Generalization of Thiel's U or the Janis coefficient is an attractive first step. Research is needed to determine better methods to facilitate entry, problem finding,and continuing use. This will require inter-disciplinary work between behavioral and management scientists to find the best approach to the planned organizational change required by models. Research is needed to develop procedures to explicitly measure the personal, organizational and decision impact of models.

For example, is the hypothesized relationship between model building detail and perceived benefits in figure 6 true? A final behavioral project is to research the diffusion of innovation process in terms of characteristics of organizations and decision makers who are most likely to accept models.[48]

Another issue raised by the methodology is ethics. It is possible with the degrees of freedom in fitting and the complexity of the mathematical translation of the model that the model builder could exert undue influence. Indeed, with an understandable and controllable model, the manager and/or model builder can produce whatever answers they want. The explicitness of the model assumption and the tracking procedures provide some protection against such manipulation, but professional ethics are required. This can be approached by appropriate academic training of model builders that includes "hands on" training in how to build models and develop professional standards for "fitting" and managerial use. This is a particularily difficult issue in view of the political roles the model builder and manager may be called upon to play.[49]

It is hoped that this emerging process of building models backed by professional model builders and additional research work will develop into a methodology which will make real to managers the promise of management science, models, and information systems.

FOOTNOTES

1. Even in the oil industry implementation of OR is not great as might be expected. See McKinsey and Co. Inc. "A Limited Survey of Industrial Progress in OR" in R. N. Learner (ed.) The Management of Improvement (Reinbold Publishing Co., New York, 1965) which states ". . . while there is a number of instances of technical success - an analytic model has been developed - in many cases, OR has not yet had a real impact on how companies plan and make decisions."

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